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Urological Neurology and Urodynamics

RESULTS OF THE TREATMENT OF NEUROGENIC BLADDER DYSFUNCTION IN SPINAL CORD INJURY BY SACRAL POSTERIOR ROOT RHIZOTOMY AND ANTERIOR SACRAL ROOT STIMULATION

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ABSTRACT

Purpose: We evaluated the results of treatment of neurogenic bladder dysfunction in spinal cord injury by sacral posterior root rhizotomy and anterior sacral root stimulation using the Finetech-Brindley stimulator.*

Materials and Methods: In 52 patients with spinal cord lesions and urological problems due to hyperreflexia of the bladder complete posterior sacral root rhizotomy was performed and a Finetech-Brindley sacral anterior root stimulator was implanted. All patients were evaluated and followed with a strict protocol. A minimal 6-month followup is available in 47 cases.

Results: Complete continence was achieved in 43 of the 47 patients with 6 months of followup. A significant increase in bladder capacity was attained in all patients. Residual urine significantly decreased, resulting in a decreased incidence of urinary tract infections. In 2 patients upper tract dilatation resolved. In 3 patients rhizotomy was incomplete and higher sectioning of the roots was necessary. One implant had to be removed because of infection.

Conclusions: The treatment of neurogenic bladder dysfunction in spinal cord injury by anterior sacral root stimulation with the Finetech-Brindley stimulator in combination with sacral posterior root rhizotomy provides excellent results with limited morbidity.

KEY WORDS: bladder, neurogenic; spinal cord injuries; electric stimulation

In patients with complete spinal cord injury at a level that leaves the sacral segments intact detrusor hyperreflexia develops after a phase of spinal shock.¹ This type of bladder dysfunction is responsible for important morbidity.^{2,3} Anticholinergic therapy is the usual treatment but it is often inadequate.⁴ However, continence is important in wheelchair bound patients since treatment with protective materials is problematic.⁵ Furthermore, inefficient bladder emptying often leads to the need for permanent intermittent catheterization.⁶

High pressure bladder contractions produce secondary changes in the detrusor muscle and a low volume, high pressure bladder may cause decompensation of the upper urinary tract.^{7,8} The mechanism of upper tract changes is usually vesicoureteral reflux in combination with infection.^{9,10} Careful followup and even surgical treatment modalities, such as sphincterotomy, are not always successful in reducing urological morbidity.^{11,12} Patients with cervical spinal cord lesions may have severe autonomic dysreflexia on bladder filling,¹³ which can be dangerous and difficult to treat.

Electrical stimulation of the bladder as a means of overcoming these problems has generated a great deal of interest.¹⁴ The surgical technique has been modified with time and recently sacral anterior root stimulation has been combined with complete posterior sacral root rhizotomy to abolish all reflex activity of the detrusor.¹⁵ Preliminary results

with this combined technique suggest better clinical results than in earlier series.¹⁶ With better knowledge of the neuroanatomy of the sacral roots and innervation of the lower urinary tract posterior sacral root rhizotomy has gained new popularity with promising urodynamic and clinical results.¹⁷ To our knowledge only small series with limited followup results have been reported previously on the combined technique of posterior sacral root rhizotomy and implantation of a sacral anterior root stimulator.

MATERIALS AND METHODS

Between January 1989 and May 1995, 52 patients with spinal cord injury and severe dysfunction of the lower urinary tract that could not be cured by maximal conservative treatment underwent intradural sacral posterior root rhizotomy and implantation of a Finetech-Brindley anterior sacral root stimulator. The stimulator was implanted in 29 men 17 to 57 years old (mean age 37.2) and 23 women 16 to 44 years old (mean age 28.6). Mean age of all patients was 32.9 years. The high proportion of women is explained by the fact that at the onset of the stimulation regimen the majority of possible candidates were female and had severe incontinence. After initial good results more male patients with a spinal cord injury became interested in this treatment.

The cause of the spinal cord lesion was trauma in 50 patients. One patient had a proved complete spinal cord lesion after a vascular accident and a woman had a complete spinal cord lesion due to birth trauma. The lesion was complete in all patients. Maximum duration of the spinal cord

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lesion at operation was 22.5 years (mean 6.25). Mean period between the injury and surgery was 6.0 years in the female and 6.5 years in the male patients. Since the neurological and personal situations must be stable a minimal interval of 9 months was required before implantation.

Different levels of spinal cord lesion were represented. In 11 patients the lowest clinical level of the lesion was cervical, of whom 7 had autonomic dysreflexia. A thoracic lesion was above T6 in 14 patients and below T6 in 27. At evaluation 14 patients emptied the bladder by suprapubic tapping alone, and 9 used a combination of tapping and medication to reduce outlet resistance. A total of 17 patients used a combination of suprapubic tapping and a variable frequency of intermittent catheterization. Four patients used intermittent catheterization only and 8 had an indwelling catheter.

A minimal followup of 6 months was available in 47 of the 52 patients. No significant changes in bladder behavior or the effectiveness of bladder stimulation occurred after 6 months. A followup of at least 1 year is available in 44 cases and 2 years in 35. Maximum followup was 76 months. Mean followup in the group of 47 patients with a minimal followup of 6 months was 42.2 months.

All patients were evaluated according to a standard protocol, including a detailed study of the anatomy and function of the upper urinary tract. Urodynamic testing included medium fill (35 ml. per minute) cystometry with water at body temperature to measure maximal cystometric bladder capacity and rapid fill (100 ml. per minute) cystometry with ice water to control for the presence of reflex detrusor activity. Candidates for a stimulator needed to have an ice water test response of greater than 50 cm. water, indicating preserved sacral reflexes and sufficient detrusor contractility. If detrusor contractions of less than 50 cm. water were present, percutaneous sacral root stimulation at the level of the sacral foramina was performed. Patients were considered candidates if a bladder contraction of at least 50 cm. water occurred during acute stimulation.

The main reason for treatment with sacral posterior root rhizotomy and implantation of a sacral anterior root stimulator in female patients was incontinence. In men the main indication was the presence of a large residual after bladder emptying, most often due to severe detrusor-sphincter dyssynergia. Of the 11 patients with a cervical lesion severe signs of autonomic dysreflexia were a supplementary reason for rhizotomy in 7. No form of previous conservative treatment was considered a contraindication for surgery if a minimal bladder capacity of 200 ml. was preserved. All patients performed intermittent catheterization or learned to do so because of the possible need for catheterization in case bladder stimulation failed. Six patients had an indwelling catheter for a mean of 4.2 years preoperatively (range 6 months to 6.3 years). Sphincterotomy had been performed previously in 4 men.

The technique as previously described was performed in all patients.¹⁸ Briefly, after an intradural approach the sacral roots were identified with electrical stimulation based on somatomotor reactions and bladder pressure increase. Rhizotomy of all posterior segments of S2 to S4 was done. In 3 patients there were difficulties with the splitting of anterior and posterior segments of the sacral roots. These patients presented postoperatively with persistent reflex activity and rhizotomy at the conus medullaris was necessary to control bladder function. No major perioperative problems occurred and median blood loss was 320 ml. (range 60 to 650).

Stimulation was started between days 3 and 5 postoperatively. After a regimen was determined for stimulation of the bladder and rectum patients were instructed how to use the external equipment. Mean hospital stay was 10 days (range 8 to 21). All patients were followed according to a fixed protocol. A general and urological history was obtained, and a physical examination with ultrasound of the kidneys was

done 6 weeks after surgery and every 3 months thereafter during the first year. Stimulation parameters were controlled and adjusted based on clinical and urodynamic results. Urodynamics, ultrasound of the kidneys and a 24-hour creatinine clearance test were repeated after 6 months and every year thereafter.

RESULTS

Postoperative followup of a minimum of 6 months is available in 47 of the 52 patients. Because no significant changes in bladder behavior or the effectiveness of bladder stimulation occurred after 6 months in patients with complete posterior rhizotomy and no persistent reflex activity at cystometric followup, analysis of the results is based on these 47 patients.

Bladder capacity. During the first weeks after surgery bladder capacity and compliance were still limited but both gradually increased within 6 weeks.¹⁹ Mean maximum bladder capacity of 596 ± 104 ml. (range 374 to 792) was attained on cystometry 6 weeks postoperatively and remained stable with longer followup. Patients were advised to empty the bladder at about 500 ml. although in the majority higher capacities can be achieved. In our series 18 patients noticed an occasional bladder capacity of more than 1,000 ml., apparently without any damage to the detrusor muscle.

In 1 female and 2 male patients bladder capacity with natural filling was limited to about 400 ml. because of incontinence due to reflex activity of the detrusor. In these patients voiding was impossible, although high intravesical pressures occurred with stimulation because of electrically induced detrusor-sphincter dyssynergia. After posterior rhizotomy was performed at the level of the conus medullaris bladder capacity increased significantly. However, severe stress incontinence developed in 1 man.

Continence. At the most recent followup 43 patients were completely continent. However, 10 women noticed overflow incontinence when the bladder was filled to greater than 800 ml. We have not evaluated this finding on urodynamic testing due to the possibility of inducing detrusor injury but intravesical pressure under these conditions may be higher than maximal urethral closure pressure, causing leakage. Mild stress incontinence also occurred at smaller volumes in 3 men, including 1 who underwent sphincterotomy before implantation of the bladder stimulator. One patient presented with severe stress incontinence after rhizotomy at the level of the conus medullaris.

Bladder emptying. At the most recent followup 41 patients used the stimulator alone to empty the bladder. One female and 3 male patients combined use of the stimulator with regular intermittent catheterization because of persistent residual urine. The woman underwent implantation of an extradural stimulator after removal of the intradural stimulator due to infection. After stimulation 100 ml. residual urine remain, necessitating intermittent catheterization twice daily. Intermittent residual urine in the 3 other patients is probably due to inadequate positioning of the transmitter since the bladder empties completely when the external stimulator is used correctly. However, these patients prefer to eliminate residual urine via occasional intermittent catheterization, depending on the quality of voiding. Two patients depend on intermittent catheterization because implant driven voiding is not possible. In a 56-year-old man electrical stimulation of the sacral roots is not feasible, probably because of permanent nerve damage. One woman receives high doses of parasympatholytic oxybutynin to decrease sweating, which makes bladder stimulation impossible. However, she is continent and free of infection.

Residual urine and urinary tract infections. In all 41 patients who use the stimulator for evacuation of urine residual urine after a complete stimulation cycle is less than 50 ml. In

the 44 patients with a followup of at least 1 year the mean incidence of urinary tract infections decreased from 4.2 (range 2 to 12) in the year before surgery to 1.4 (range 0 to 2) during the last year of followup.

Upper urinary tract function. Dilatation of the upper tract with signs of obstruction noted preoperatively on renal scintigraphy in 2 patients resolved within 6 weeks after complete sacral rhizotomy. With further followup electrical stimulation had no detrimental influence on the aspect of the upper urinary tract. Postoperative creatinine clearance testing revealed stable kidney function in all patients, although 32 had had reduced clearance preoperatively. Renal scintigraphy revealed no signs of obstruction or kidney function loss after surgery. Two patients had asymptomatic vesicoureteral reflux on preoperative cystography, which disappeared 6 months after surgery in 1 and decreased with daily electrical bladder stimulation in 1.

Autonomic dysreflexia. Seven patients with a cervical lesion presented with severe signs of autonomic dysreflexia. In 4 patients spontaneous dysreflexia with bladder filling resolved with larger volumes. In 2 patients limited stimulator induced dysreflexia developed that did not prevent stimulator use.

Defecation. The 41 patients who use the stimulator for evacuation of urine clearly benefit from a separate stimulation regimen that decreases the total time of defecation. In 17 patients the stimulator alone is used and 24 also required some form of enema. Depending on the consistency of the fecal material manual evacuation is needed in 14 patients but the stimulator is used to bring the stool low in the rectum. Patients who cannot use the stimulator for defecation continue to use the preoperative method and frequency of defecation. No patient found the operation detrimental to defecation.

Penile erection. Rigid penile erection with continuous stimulation of the S2 roots was possible in 18 of the 29 men. However, since rather high voltages are used to induce erection, strong lower limb contractions occur during this type of stimulation. Therefore, only 6 patients reported using stimulator induced erections for coitus.

Spasticity. The degree of spasticity in the postoperative period varies greatly among patients. Spasticity in all patients returned to the preoperative level. However, due to the improved quality of life with the resolution of incontinence, these problems receive more attention. Therefore, 2 women requested further treatment for spasticity and an intrathecal baclofen infusion was implanted 3 and 2 years after implantation of the bladder controller, respectively.²⁰ Voltages for stimulation of the bladder were increased to permit complete voiding but no further effect on bladder function was documented. One patient had already had a baclofen infusion implant before implantation of the bladder controller. There was no interference with bladder stimulation.

Complications. Two patients had a cerebrospinal fluid leak during the early postoperative period, which was treated conservatively with the Trendelenburg position, and both leaks sealed spontaneously. In 1 patient a wound infection initially resolved with antibiotic treatment but 3 months after implantation a low grade implant infection occurred and the implant was removed. After implant removal the patient remained continent with a large bladder capacity. An extradural sacral root stimulator was implanted 6 months later. In 2 patients the initial bladder reaction as well as the motor responses of the lower limbs disappeared 7 days after surgery, probably because of nerve damage. One patient recovered after 6 months but 1 recovered only partially after 18 months and still requires intermittent catheterization because of insufficient bladder emptying due to low pressure detrusor contractions. Apparently this patient has permanent nerve damage.

Implant failure. No implant failures have occurred to date.

Some minor problems developed with the external control box. However, when there are defects in the external equipment the patient depends on intermittent catheterization for voiding until a reserve stimulator box becomes available.

DISCUSSION

The management of neurogenic bladder dysfunction after spinal cord injury is difficult since the goals of therapy are to increase bladder capacity, maintain low pressure storage of urine with preservation of the upper urinary tract and prevent incontinence. Furthermore, voiding without any residual should be achieved to decrease the incidence of urinary tract infection. Posterior sacral root rhizotomy has been advocated to reduce or resolve detrusor hyperreflexia and to improve detrusor responses to anterior sacral root stimulation. Results of limited posterior rhizotomy were disappointing and, therefore, complete posterior sacral root rhizotomy from S2 to S4/5 was recommended.¹⁵

A sacral anterior root stimulator, the Finetech-Brindley bladder controller, has been available since 1984 but only recently has complete sacral posterior root rhizotomy combined with implantation of this stimulator gained general interest. A limited number of reports of the combined technique are available. A consistent problem with these studies is short followup and a limited number of patients. We report on 52 patients with a spinal cord lesion in whom the Finetech-Brindley anterior sacral root stimulator was implanted after complete sacral posterior root rhizotomy, and we evaluated the clinical effects of this treatment.

Good results were achieved in terms of increase in functional bladder capacity, continence and evacuation of urine with significant reduction in the incidence of urinary tract infections and improvement in upper tract function. Even after several years of neurogenic bladder dysfunction, rhizotomy resolved spasticity of the detrusor and resulted in a permanent areflexive bladder with low intravesical pressure, large capacity and high compliance. Our results refute previously reported experience that detrusor hyperreflexia recurs, especially in patients with a spinal cord injury.^{21,22} Good results were noted in a smaller series with complete posterior sacral rhizotomy.²³ No patient in our series noticed a decrease in capacity with time, although there was a limited increase in bladder capacity in 3 patients who did not undergo complete rhizotomy. They subsequently underwent secondary posterior rhizotomy at the level of the conus medullaris and bladder capacity increased significantly. These findings may explain the variable results in previous series in which rhizotomy was performed depending on perioperative stimulation results.²⁴ Therefore, we recommend posterior rhizotomy from S2 to S4/5 in every patient since no preoperative or perioperative tests allow for localization of the presence of afferent parasympathetic fibers in the sacral roots.

The primary purpose of the Finetech-Brindley bladder controller is to improve the evacuation of urine. Since 41 of our 47 patients empty the bladder with the stimulator alone, this goal was achieved in the majority. Based on the long-term results of this initial series we may expect favorable long-term results after activation of the bladder succeeds.²⁵ The permanent loss of activation of the bladder after 5 days in a 57-year-old patient may indicate that the sacral nerves in older patients may be more prone to intraoperative damage and have a more limited recovery. Further experience in older patients will allow the evaluation of whether patient age is important in the selection of candidates for this form of treatment.

Limited stress incontinence can develop in male patients but the explanation of this phenomenon is uncertain.²³ The majority of men who were candidates for sacral root stimulation had an open bladder neck on preoperative cystogra-

phy. Increased bladder capacity could unmask stress incontinence based on pelvic floor insufficiency that was not evident before the operation. The anatomy of the bladder neck must be studied during the screening of male patients and they should be informed about the possibility of postoperative stress incontinence. However, the improvement in bladder emptying largely compensates for this minor incontinence problem. In female patients with spinal cord injury regaining continence is perhaps the major goal of treatment. All of our female patients are continent even with bladder volumes greater than 500 ml. Similar excellent results in women have been reported in another series.²⁶ In patients with a cervical lesion and poor hand function assistance from another person may be needed to activate the bladder controller. Therefore, the daily life environment of each candidate must be considered. However, especially in female patients with a cervical lesion, the comfort of continence largely compensates for these inconveniences.

In the majority of patients there was clear improvement in the defecation pattern. Although defecation problems were not an indication for surgery without severe bladder problems, the effect on defecation can be considered a positive by-product of urological treatment. In our series 60% of the men had stimulator induced penile erections but only a third reported using the stimulator as an aid to sexual activity. Due to the uncertain effect of stimulation on penile erection male candidates for this surgery should be willing to lose reflex erections.

CONCLUSIONS

Our results with the combined technique of posterior sacral root rhizotomy and sacral anterior root stimulation illustrate the good outcomes that can be achieved with this method. However, careful selection of patients is essential. Complications can develop and in patients with balanced detrusor hyperreflexia the possible risks of surgery must be considered.

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